Cameco, Key Lake Regreening Project, in Harmony with Nature (1978-1999 & beyond)

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Abstract: Cameco, Key Lake Operation is located in North-Central Saskatchewan, on the southern boundaries of Athabasca formation. Exploration in the early seventies led to the discovery, development and mining (1982-1997) of two uranium ore bodies, the Gaertner and Deilmann pits. The regreening of the disturbed areas at Key Lake started in late seventies when numerous experimental plots were set up to study the establishment and survival of various agronomic species and their adaptability to the harsh environmental conditions in the Athabasca Region of northern Saskatchewan.

The objectives of the initial program were to: reduce soil erosion and dusting, rebuild the top layer and improve aesthetics. Most of these objectives were achieved by the development of a small annual hydroseeding program that stabilized the high traffic areas and slopes of embankment areas such as reservoirs and tailing pond. However, the ultimate goal of reclamation is to return the land to a self-sustaining state similar to its pre development state. The existing program was found unsustainable, and as a result, in 1993 Cameco augmented its previous research activities to enhance the long-term viability of the revegetation program. Various native grasses, shrubs and trees were cloned and transplanted in the nursery, planted in experimental plots, and studied over a five-year period. This led to the successful planting of nearly half a million jack pine seedlings native to Key Lake, the establishment of two native grass seed farms, the development of a five-year plan and changing the status of about 165 hectares of disturbed land too undisturbed.

By 1996, a methodology was also developed for regreening flat areas where a disturbed area could successfully be stabilized and tree-planted within the same year which led to the development of a five-year revegetation plan. However, the methodology applied to flat areas may not necessarily be applicable to large sloped areas ie, waste rock piles. In 1998, various sloped areas were identified and a research program developed and applied to the slopes. The objective of the program was to identify factors affecting soil erosion and stabilization on the slopes. In July of that same year, Key Lake experienced a one in a one-hundred-year storm event which washed away many of the research plots established earlier in the year, thereby proving that surface erosion may not be the only issue on the slope areas.

To date, research and experiences gained, indicate that the best method to stabilize a site is to follow a methodology which is similar to the pattern in nature and utilize native species from the surrounding area. To enhance the process, native or imported pioneering species capable of stabilizing and paving the way for the climax species must be used. The research also indicates that even though the slope areas pose similar challenges as the flat areas, the issue of erosion control on slopes is far more complex than on flat areas.

1.0 INTRODUCTION

The concept of ecological succession leading to the stable steady-state vegetation (climax) of a disturbed site such as mining has been well documented. However, since the reclamation specialist has to deal with numerous and often competing site specific factors, he or she has to use experiments to test the nature of the site and what works best. In other words, reclamation could be and often is site specific. To identify the most adaptable species and economical method of reclaiming the disturbed sites at Key Lake, numerous experimental plots between 1978 and 1986 were set up and studied. The present hydroseeding program is partially the result of these studies. However, due to competing priorities for a limited manpower, not all the results were properly documented. Also, at times many variables were changed at the same time, making it difficult to interpret the results. Therefore, in 1993, Key Lake Operation augmented its research program to include pioneer and climax species and the relation between the two.

The new research program had two arms - the laboratory program, where scientific research was performed on actual plants from the site and the field program, where various pioneer species and jack pine seedlings (the predominant climax species) were studied under site conditions. The study started in 1993 and ended in 1997. The result was the development of a process that has proven successful to reclaim flat areas of the site. The most important factors affecting the survival of plants regardless of species are the genetic of the species and the damage due to wind erosion. Therefore, if the plants are properly selected and wind erosion eliminated, the growth rate of plant would depend on other factors such as nutrient availability which are relatively easier tasks to perform.

After successful development of the above methodology the research team focussed its attention on the development of a proven methodology to reclaim the slope areas, such as the slopes of waste rock piles and river crossings and large trenches. As a result, in 1998 a research program was established to study various factors on sloped areas. This program is ongoing.

1.1 Background

Key Lake Operation is a joint venture between Cameco Corporation and Cogema Resources. It is located in north-central Saskatchewan, about 70 km east-southeast of Cree Lake (Figure 1) at an approximate latitude of 57°11' north and longitude of 105°34' west. It lies within the southern boundary of the Athabasca basin, a geological formation composed of flat lying pre-Cambrian sediments (mainly sand and granules). The glacial erosion of this material left a landscape composed largely of nutrient poor sandy material.

The project started in 1982 with the open pit mining of Gaertner ore body which was mined out in 1987. The open pit mining of Deilmann ore body commenced in 1986 and was completed in 1997. The milling activities of Deilmann ore are expected to continue until early 2000.

As a result of the mining activities, close to 1,000 hectares of land has been disturbed which requires reclamation. This includes the building sites, Tailings Management Facilities, the reservoirs, monitoring ponds, the airport, the roadways, waste rock piles, lay down areas, the borrow pits, the residential camp, etc.

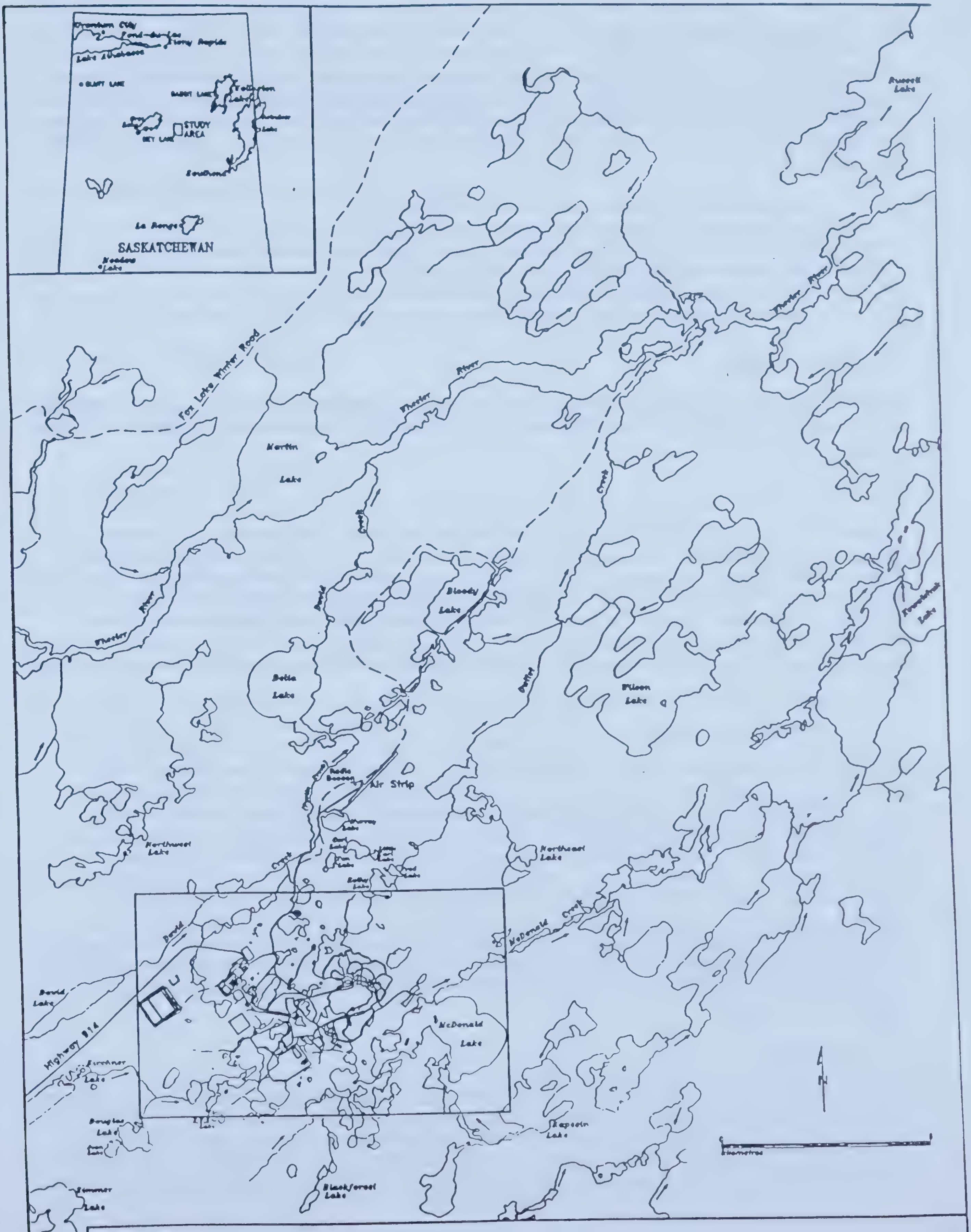

FIGURE 1. Study area and study location.

2.0 Objectives of the Program

The overall objective of the program is best described in the Key Lake five-year revegetation plan as "To return disturbed areas of the Key Lake mine site, to a stable, vegetated state, similar to the pre mining era, through the development of a mosaic of habitat types and erosion control techniques, to enhance the establishment of long-term natural vegetation" social and economic considerations taken into account. However, the specific objectives of the program are to:

- Identify the species most suitable to the conditions of the site.
- Utilize as much as possible species native to Key Lake area.
- Harvest seeds that are native to Key Lake through establishment of seed farms.
- Develop a methodology to revegetate the flat and slope areas.
- Develop a criteria for the revegetation of disturbed sites.
- Satisfy Cameco's license requirements as far as reclamation at Key Lake is concerned.

3.0 Site Description

There are many features of a site that directly impact the reclamation/revegetation of disturbed areas. The following is a brief description of various features of Key Lake site that determine plant species native to Key Lake and their growth rates.

3.1 Soil

There are five types of soil identified in the Key Lake area, i.e., till, glaciofluvial, eolian Sand, slope wash, and organic deposits. Soils, where developed, are thin and underlain mostly by sand, well-drained and exhibit low moisture-holding capacity. As a result, the Key Lake area is unsuitable for agriculture or pasture land. All mineral soils at Key Lake area have low nutrient status, Cation Exchange Capacity (CEC), pH, and Electrical conductivity (EC) and are classified as sand textured. As a result, these materials are considered poor media for revegetation. The organic soils (associated with muskeg and riparian areas) have significantly higher nutrient contents, CEC and moisture, but lower pH than mineral soils and are considered better media for revegetation. However, they are very scarce.

3.2 Climate and Meteorology

Key Lake lies within the Boreal climatic zone, which covers Canada from Alaska to Newfoundland. Boreal climates are influenced by cold arctic air masses causing long and frigid winters and cool, moist northern pacific air masses which enter the region during generally short and cool summers. The Key Lake climate, therefore, is characterized by short, cool, moist summers with a mean monthly temperature of 15.85°C in the warmest month (July) and long, cold winters with a mean monthly temperature of -23.21°C in the coldest month January. Temperature extremes of mean monthly temperatures are typical of northern Saskatchewan. The total annual precipitation has averaged 457.36mm over the 1977 to 1998 period with 66.86% of the precipitation falling predominantly as rain over the summer months. The average pan evaporation rate over the same period was 652.93mm (Annual Report, 1998). Average annual wind speed in the region is less than 16 km/hr, with maximum speeds between April and October, and relatively calm periods during winter which reduce the incidence of extreme wind chill conditions. Winds from the west quadrant (SW-W-NW) and north quadrant (NW-N-NE) predominate (TAEM & SENES, 1994).

3.3 Vegetation

Vegetative cover in the Key Lake area is generally a function of landform. There are two general vegetation types - 1) Forest type and 2) wetland type. The forest type occupies a well drained, treed upland sites whereas the wetland type occurs in poorly drained peat or sedge lowland sites. The vegetation cover at Key Lake is almost entirely of jack pine, with only small patches of Black Spruce. Jack pine forests are found on upland areas with coarse textured soil. This includes both open jack pine forest with little ground cover (few or no shrubs, blueberry plants, lichen, etc.) and closed forests with dense shrub and forb in understorey. Most jack pines in the Key Lake area are from 85 to 150 years old, and forest productivity and species diversity are lower than other areas in the Athabasca basin. Vegetation in low lands with organic soil, and poor drainage is typically dominated by open black spruce forest with an understorey of shrub and moss. Tamarack and swamp birch are also present in lowland areas, but are less common. Other predominant vegetative cover in wetlands are wet sedge meadow and rush-sedge cotton grass meadow.

4.0 Research Program for Flat Areas (1976-1995)

Immediately after exploration a research program was started which lasted until 1986. The program resulted in a hydroseeding program with criteria for the type, quantity and rate of materials to be applied. The research program was expanded in 1993 to include the climax species, i.e., the jackpine trees. The program culminated in a complete and successful reclamation program for all flat areas at Key Lake. The following subsections briefly describe these research programs.

4.1 (1976-1986) Research Program

Due to unforgiving environmental conditions, the invasion of trees and shrubs to a disturbed area is a very slow process. As a result, numerous studies were performed from 1978 to 1986 to identify the most effective:

- agronomic and native species;
- site preparation method;
- seeding methods and rates;
- fertilizer application methods, rates, timing and frequency;
- irrigation rates and methods;
- tree planting and maintenance procedures;
- soil amendments (lake sediments, lime, mulches, tackifiers, peat, hydrophillic agents); and
- transition from agronomic to self-sustaining vegetative cover.

Based on these research activities the following conclusions were made:

- The most successful species were: boreal red fescue, sheep's fescue, Carlton smooth brome, annual ryegrass and Fairway crested wheatgrass.
- None of the legumes tested survived past the first year.
- The native plants indicated low survival rates. In addition, they were found too costly and therefore, not recommended for large scale reforestation programs.
- Containerized jack pine, if not fed upon by animals, survived well and is preferable to bare roots.
- Seeds that are not covered by soil, hardly ever germinate and are easily blown away or eaten by birds. The seed could be harrowed, raked or covered by mulch. Seed application rates of 100 kg/ha was found to be the most effective.
- Hydroseeding, despite its disadvantages, was found to be the most suitable and economic method for large scale revegetation application.
- The soil analysis indicated that the soil media is deficient in all major nutrients. An initial application of 100 kg/ha for each of N, P_20_5 and K_20 followed by an annual application of 100 kg/ha of N and P_20_5 was proven to be very successful. Also, the timing of the application is very important (Courtney, 1987).

4.2 1993-1995 Research Program

1993-94 Research Program

The new research programs had two components - laboratory and field programs. The laboratory program was composed of identifying species that grow naturally in the Key Lake area (both the pioneering and climax species) and collecting seeds, samples or specimens from them and propagating the species in the nursery and transplanting them in the field under various conditions. The key was to find the native species that could adapt themselves from ideal conditions in the nursery to the harsh conditions at the site.

The field program was composed of planting the actual native plants grown under laboratory conditions and the most prevalent species (e.g. jack pine seedlings) and study the major factors affecting their growth and performance under various conditions. These factors may include, but not limited to:

- genetics of the species to be planted;
- soil quality, slope and aspect of the area;
- exposure to wind and the associated abrasion;
- ongoing erosion of the area; and,
- moisture regime.

The focus of 1993 experimental season, was making a comparison between hydroseeded and non-hydroseeded areas of the mine site. This was to examine the potential competition between the grasses and the jack pine seedlings. The study sites were selected and the seedlings planted. The treatments used were; Control, Peat Slurry Dip, Alcasorb Root Dip, Wood Chip Protection, Shingle Protection, Desert Tamer and Tire Protection.

The experimental design for 1993 consisted of a single treatment for each plot. The design of the plots was somewhat different in 1994, with each plot composed of 5-6 rows, with each row receiving a different treatment. This change was made to avoid bias to any treatment, due to differences in soil quality, exposure or moisture regime at a given site.

Fertilizer stakes used in 1993 were omitted from the 1994 study, as they were noted to "burn out" the seedlings and enhance competitive grass growth around the trees that did survive. The other amendment that was deleted from the 1994 study, was shingles placed on the south side of the seedlings. Although this was meant to shade the area to slow down moisture loss, the trees were noted to be growing to the side, apparently attempting to get into direct sunlight.

1995 Research Program

In order to address the utilization of native vegetation species for reclamation at Key Lake, several species were collected (i.e. plants and cuttings) from northern Saskatchewan and propagated in the greenhouse. These species include:

Grasses
Calamagrostis neglecta - narrow reed grass
Carex foenea - hay sedge
Bromus pumpellianus - northern awnless brome
Festuca rubra - red fescue
Calamagrostis inexpensis - northern reed grass
Agrostis scabra - rough hair grass

Woody Species
Vaccinium sp. - blueberry
Salix sp. - willow
Populus balsamifera - balsam poplar
Populus tremuloides - trembling *aspen*

Chamaedaphne calyculata - leatherleaf
Betula sp. - birch
Prunus pennsylvanica - pincherry
Pinus banksiana - jack pine

Three sites were chosen that represented the environmental conditions at the Key Lake. At each site an experimental plot design with 16 plots representing 4 replicates of each of the following treatments, was set up:

T1 - Control with no wind fence and no hydromulch and fertilization
T2 - Wind protection (snowfence) with no hydromulch
T3 - Wind protection (snowfence) with hydromulch
T4 - No wind protection (exposed) with hydromulch

The grass plugs were planted in the perimeter of each plot. Also 70 jack pine seedlings (7 rows of ten seedlings each) were planted on each plot. The experimental sites are; Site 3-Moderately harsh environment, Site 17 - Mild environment and Site 21 - Extremely harsh environment (a south-facing slope of the waste rock pile with modified slopes of a 3.5:1).

Additional Experimental Seedling Plots 1995

Site 4 -Mill Hill area directly between the mill and the mine shop. Four 10m x 10m plots were established; two on the crest of the hill and two on the side-slope facing the mine shop. At each location, a control plot and a plot treated with approximately 6.25 kg of lime were set up. At each plot, 100 jack pine seedlings, were planted.

Site 21 - Treatments that were tried at this location include slope modification and seedling protection. These plots were located west of the grass experimental plots and consisted of the following:

Small shallow pits (shelter pits), approximately 20 cm wide and 10 cm deep were dug, with the soil from the hole placed on the north side of the seedling. The intent of this treatment was to create a small wind protection mound for the seedling, while creating a depression to hold moisture. The seedling was planted half way up the created slope to be protected by the mound, but not flooded.

A portion of the side-slope of Site 21 was delineated into four-100 metre sections. Two sections were altered by walking a bulldozer perpendicular to the slope to create a series of ridges on the slope-face. The intent was to create a more protective, stable environment for the seedlings to become established, particularly during the first year. The ridges decrease the erosive force of the wind, protect the seedlings from the abrasive blowing sands, aid in moisture retention and erosion caused by runoff. The other two sections were left untreated, with respect to terrain alteration.

Half of the Control and the Ridged areas were covered with mulch to determine the effects of the added erosion control. All four areas were then planted with jack pine seedlings. Due to uneven ridges, the number of seedlings in each area were not identical.

Site E-This site is located immediately north of the Gaertner Pit and is exposed, with little surrounding cover. Due to the exposure plants in this area are subjected to "sand blasting". In addition, seeds are blown away from the area prohibiting seed germination. In Site E several treatments were established in an attempt to protect the seedlings from the wind and blowing sand. The treatments were: pits, control, shingles, alcosorb and windfence (Johannessen et al, 1995).

Windfence - An area of approximately 12m x 12m was surrounded by a commercially available plastic windfence. The windfence was porous and was used to provide a wind break, thereby decreasing the wind speed and minimizing the abrasive effects of the sand. The fence may also enhance moisture retention of the soil by decreasing evaporative potential of the wind. This will allow the seedlings to better establish themselves.

Grass Seed Mixture Trials

At Sites 3, 17 and 21 grass seed mixture trials were conducted to determine the success of commercially available cultivars, including: Durar hard fescue, Streambank wheatgrass, slender wheatgrass, Canada blue grass, northern wheatgrass, and creeping red fescue. The areas were fertilized at a rate of approximately 27.5 kg/ha of nitrogen and 5.7 kg/ha of potassium. The seeding rate was approximately 1.5 kg/ha, with the seeds broadcast seeded and lightly raked. Each plot was 2m x 2m. At each of the three sites, one series of plots was covered with hydromulch, and the others used as a Control.

Seedling Development Experimental Area

This plot was established in Site C (existing site 25) for the measurement of root and stem development of the seedlings planted in 1995. Every 4-6 weeks, 10 seedlings were collected and the length and dry weight of the stem and roots of the seedling were measured. This allowed the researchers to evaluate the development of the seedlings and to determine the shoot : root weight ratio of the seedlings. The frequency of this program was reduced to once a year in 1996 and 1997. This monitoring program is not performed any more.

The measurements were taken from collar to shoot tip and collar to root tip. The samples were cleaned of their rooting medium and dried for 48 hours at 50° C. Care was taken not to remove fine rootlets. After the samples were dried, their weights were determined with a Mettler electronic balance at the Key Lake chemistry laboratory.

In addition, the shoot height and stem thickness of two hundred seedlings have been measured since 1995 to gauge the growth of the seedlings.

5.0 Research Program for Slope Areas (1998-Present)

5.1 Experiment I - Slope Revegetation

The specific objectives of Experiment I were to:

- identify the soil characteristics of the various sloped areas;
- replicate and test various treatment options on different slopes; and,
- test the "patch theory" on the slopes and flat areas of the site.

During a preliminary survey of the various slopes at site, four slope types were identified; unplantable rock slopes, plantable rock slopes, clay slopes and sandy slopes.

Unplantable Rock Slopes

At present, it appears appropriate to leave the stable, unplantable rock slopes as they are. The rocks are continually weathering and breaking down to small particles. In addition, the deciduous trees establishing themselves would enhance the weathering process. As rocks weather, and the resulting fines erode, the fines will form gentler slopes, creating a safer medium for planters to walk on.

Plantable Rock Slopes

Two (2) replicates of two different density plantings were tested on the top and bottom slopes, on a north-facing and a south-facing slope, for a total of 16 plots. The plots were approximately 2 m x 2 m in size and spaced approximately 5 m apart.

The low density plots received 2 jackpine seedlings, 1 willow or balsam poplar cutting, 1 birch cutting, 1 fireweed, 2 F. rubra plugs and 2 Deschampsia caespitosa plugs. The high density plots received 4 jackpine seedlings, 3 willow or balsam poplar cuttings, 3 birch cuttings, 6 fireweed, 8 F. rubra plugs and 8 Deschampsia caespitosa plugs. Each plot was marked with a lath in the centre of the plot for proper identification.

In these plots, the efficiency of the low versus high-density stocking to achieve coverage of the plot, and/or expansion into adjacent areas is being tested. For this reason, plants that are known to be prolific seed producers were planted. This would eventually prove the validity of planting small patches throughout the site and allow them to expand into the adjacent areas, rather than trying to revegetate the whole rocky area.

Clay Slopes

To test the potential of the grasses to expand on the soil medium of the clay areas of the waste rock piles, two (2) replicates of two (2) treatments on the upper and lower slopes on both a north-facing and south-facing slope (clay portion of Site 21 immediately south of the Deilmann Pit) were established. This corresponds to 16 plots in total.

The treatments, in 4 m x 4 m plots, were as follows:
Treatment 1 (Patch Theory) -

Each plot contains 3 rows of 15 grass plugs (C. neglecta, B. pumpellianus, and F. rubra), followed by five rows of jackpine seedlings (15 seedlings per plot), two rows of grass plugs at the bottom (D. caespetosa, C. inexpansa), and finally 3 birch and three willow or balsam poplar cuttings randomly placed among the jackpine. These plots were labeled as Plugs.

Treatment 2 -

The plot was hydroseeded with a mixture that contains commercially available boreal red fescue and 10grams of the native seed harvested from Key Lake. In addition, each plot received 15 jackpine seedlings per plot. These plots were labeled as HYDRO.

Sandy Slopes

The same treatments described for the clay slopes were applied to steep sandy slopes, that could safely be worked on, such as those on portions of Site 21. Again, south-facing and north-facing slopes in excess of 3:1 were tested, resulting in 16 plots on each slope. This should provide information on the maximum slope that could be revegetated without slope modification.

Note: All of the experimental plots were fertilized at a rate of 200 kg/ha.

5.2 Experiment II - Native Seed Investigation

Seed Viability/Germination Test

The objective of this program was to explore the possibility of directly applying jack pine and other native seeds into a disturbed area and document the results. Prior to field tests, greenhouse trials were performed under laboratory conditions. Germination and emergence of the selected seed types were tested under ideal growth conditions to provide baseline data for comparison with the field results for the same species.

To facilitate these experiments, four buckets of sand and clay were collected at Key Lake and sent to the greenhouse. Seeds harvested in the previous summer from the grass in the farms at Hourglass Lake and Site 17 were planted in trays containing either sand or clay, as well as on filter paper in petri dishes with water. Two hundred (200) seeds of each type of grass were used for each trial and repeated twice.

The coated (treatment coated and ash coated) and uncoated jackpine seeds were also germinated in the greenhouse in Key lake media to establish baseline. The same procedures described in the previous paragraph for the grass seed germination trials were followed.

Direct Seeding of Jackpine Seed and Native Grass Seed

The following design, planted on Site 21 was used to test the effectiveness and efficiency of a single application of native grass seeds and jackpine seeds harvested from the Key Lake ecoregion. This was examined using a split-plot design. A total of three blocks (replicates) were used. The five treatments were:

Treatment 1 (control) - native seed mixture + harrow + hydromulch
Treatment 2 - native seed mixture + harrow
Treatment 3 - native seed mixture + hydromulch
Treatment 4 - native seed mixture
Treatment 5 - commercial seed mixture + native seed + harrow + hydromulch

Three treatments of jackpine seeds were used randomly throughout the plots, and are described below:

1 - uncoated stratified seed (S1) – red

2 - coated, stratified seed - ash type (S2) - green

3 - coated, stratified seed - regular type (S3) - orange

The color-coding refers to the corresponding spray paint on the stakes marking the plots.

Prior to planting, the site was harrowed and staked out into three blocks of five 4m x 4m plots with 5m between plots in each block and between blocks. Each plot was labeled with `meanstreak' permanent marker and spray painted. Using a hand held spreader, each plot received 10 grams of the above seed mixture (equivalent to 60 kg/ha). After each plot was seeded, four rows with each containing fifty jackpine seeds were manually applied to the plots.

Three additional plots were added to the east side of the area and labeled S1T6, T7 and S1T8, with the treatments described below:

S1T6 - native seed mix + harrow + hydromulch + uncoated jackpine seed + 15 jackpine seedlings

T7 - native seed mix + harrow + hydromulch + 15 jackpine seedlings

S1T8 - native seed mix + harrow + uncoated jackpine seed + 3 birch seedlings + 3 willow cuttings

Finally, a border designed to provide shelter for the plots was established. The border consists of commercial seed that was planted and harrowed, and four rows of willows, birch and balsam poplar. All plots and borders were fertilized at a rate of 200kg/ha.

5.3 Permanent Monitoring Plots

Thirty six (36) permanent monitoring plots were established within representative revegetation sites throughout Key Lake. The plots were located to ensure complete representation of all site types (e.g., exposed versus protected areas; sandy soil versus clay soil). Further, the plots were sited to monitor the natural encroachment pattern of vegetation from undisturbed forest along the edges of the disturbed sites, and the revegetation pattern at the centre of the revegetation site. The permanent plots were established at 5m x 4m and marked with metal posts extending 1.5 m above the ground ensuring permanent markings of the plots.

6.0 Five-Year Revegetation Plan

The Five-year Revegetation Plan evolved out of twenty years of experimental reclamation projects (1976-1996) completed on site. The plan serves as a basis for the continuation of the regreening process of disturbed areas at Key Lake, and will be used in conjunction with ongoing experimental plots to determine the best overall reclamation approach. Thirty six sites were identified that require reclamation. The sites are described in detail, with reference to previous disturbance, existing vegetation (natural and experimental), soil texture, aspects and pH . The following briefly outline the major features of the five-year plan:

- All sites requiring revegetation that may be available over the following five years are identified at any time;
- The natural features, i.e. soil texture, slope, aspects, pH and types of natural and introduced species are identified in detail for each site;
- The best method of revegetating each site is discussed in detail and accordingly a tentative schedule has been set up;
- The plan will be used as a guide to track the success/failure of various methods that are being used at each site;
- The plan is flexible to allow new and proven methods to be incorporated in upcoming five-year plan; and
- The plan encourages the use of native and non-invasive species that are more adaptable to the climate and other environmental conditions at Key Lake.

7.0 Assessment Methodology

The methodologies used for various vegetation assessments completed at Cameco Key Lake operation, in 1998, are described in the following subsections. The 1998 measurements were taken in August and October.

7.1 Research Plot Assessments (Grass/Shrub/Jackpine)

7.1.1 Grass Growth Vigor Assessment Measurements

Measurements taken from the grasses on Sites 3, 17 and 21 were designed to provide information on vegetative growth extent and patterns, as well as the production of fruiting bodies (*i.e.,* seed heads), and are as follows:

dominant height -measured from the base of the plant to the dominant height (maximum height the majority of the grass shoots extend to). Portions of the grasses may extend higher than the dominant height;

base width - base width of the grass clump where the majority of the tillers are initiating from;

aerial extent - extent of cover afforded by the grasses for the surrounding soils;

tillers - the number of new growth tillers established during that growing season. The values were grouped into: Class 1 (1-25 new tillers); Class 2 (26-50 new tillers); and Class 3 (>50 new tillers); and,

fruiting bodies - the number of fruiting bodies (seed heads) produced by the plant during that growing season. The values were grouped into: Class 1 (1-25 seed heads); Class 2 (26-50 seed heads); and Class 3 (>50 seed heads).

Five plants were selected at random and the above measurements taken for data analysis.

7.1.2 Jackpine Seedling Assessment Measurements

To gather qualitative information on jackpine seedlings on research plots at Sites 3, 17, 21 and 34; the following measurements were taken:

shoot height - measured from the top of the collar to the tip of the apical meristem;

caliper width - width of the shoot, measured with a Vernier caliper, approximately 1 cm above the collar; and,

seedling vigor - a subjective assessment on the vitality of the seedling based on the ratio of live to dead needles. For example, Class 1 (all needles green, healthy); Class 2 (>50% green); Class 3 (<50% green); and Class 4 (shoot is dead).

Ten seedlings were selected at random from the seventy seedlings per plot, and the above measurements taken for the assessment. All measurements are in Centimetre.

7.2 Visual Assessment of Jackpine Seedling Vigor

The methodology for the 1998 visual assessment of the experimental plot jackpine seedlings planted in 1993-1995 and the grass plugs planted in 1995 have been carried each since 1994. The Ratings varied from 0 (dead) to 4 (excellent vigor) for the seedlings and a qualitative description of the grasses.

8. Results

8.1 Research Plot Assessments (Grass/Shrub/Jackpine)

8.1.1 Grass and Sedge Assessment

Tables 8.1.1 to 8.1.3 presents the survival rates for the perimeter grasses planted at Sites 3, 17 and 21 respectively. Although the survival rates vary from site to site the general trend for most species, is toward a reduction in height, increase in base width and an increase in vegetative reproduction. Seed production is abundant for most species. Nutrient availability continues to be the main growth limiting factor at all sites, as evidenced by Table 8.1.4 comparing fertilized to unfertilized treatments.

The plot treatment types at each site are as follows:

T1 - control - no wind fence, no fertilizer, no hydromulch

T2 - wind fence only (removed in autumn 1996)

T3 - wind fence (removed in autumn 1996), fertilizer and hydromulch

T4 - no wind fence, fertilizer and hydromulch

On Sites 3 and 17, only plots labeled T3 and T4 have been fertilized at 200 kg/ha each spring, while all plots at Site 21 have been fertilized yearly at 200 kg/ha.

The assessment of the grass/sedge/shrub/tree experimental plots, established at Sites 3, 17 and 21, show the importance of nutrient availability. Grasses on all plots are generally showing a trend toward vegetative reproduction and seed production, with a decrease in overall height. Plants of all species growing on the plots located at the middle and bottom of Site 21 show better growth than those located at the top of the slope. Survival rates for the perimeter grasses on these sites were as follows: Site 3 (range 82 - 96%); Site 17 (65 - 96%); and Site 21 (45 - 95%) Table 8.1.1, 8.1.2 and 8.1.3 respectively.

The plots that are not receiving fertilizer are showing a trend towards degeneration of the aboveground biomass and health. The plants on Site 3 are showing the least growth, indicating that this site is the harshest of the three. Some of the plant species (*e.g.*, fireweed, northern wheatgrass, *Agrostis scabra*) on Sites 17 and 21 are showing an affinity for spreading throughout the site. The largest cause of mortality on Site 21, is water erosion.

Table 8.1.1
Survival Rates for the Perimeter Plot Grasses
at Site 3

Species	% Survival 1995	% Survival 1996	% Survival 1997	% Survival 1998	1995-1998 Mean (%)
Calamagrostis neglecta	98	94	96	96	96
Carex foenea	96	94	84	88	90.5
Festuca rubra	93	93	94	87	91.75
Bromus pumpellianus	90	86	87	82	86.25
Mean	94.75	91.75	90.25	88.28	91.13

Table 8.1.2
Survival Rates for the Perimeter Plot Grasses
at Site 17

Species	% Survival 1995	% Survival 1996	% Survival 1997	% Survival 1998	1995-1998 Mean (%)
Calamagrostis neglecta	89	85	72	65	77.75
Festuca rubra	96	99	99	94	97.00
Bromus pumpellianus	96	93	92	92	93.25
Carex foenea	94	97	95	86	93.00
Deschampsia caespitosa	100	99	84	96	94.75
Mean	95.00	94.60	88.40	86.60	91.15

Table 8.1.3
Survival Rates for the Perimeter Plot Grasses
at Site 21

Species	% Survival 1995	% Survival 1996	% Survival 1997	% Survival 1998	1995-1998 Mean (%)
Calamagrostis neglecta	98	94	86.3	84	90.58
Carex foenea	88	80	66	45	69.75
Deschampsia caespatosa	98	97	88.5	82	91.38
Bromus pumpellianus	96	89	83	95	90.75
Festuca rubra	97	95	94	95	95.25
Mean	95.40	91.00	83.56	80.20	87.54

Table 8.1.4
Percentage Survival Comparison between Fertilized and Unfertilized Plots at Sites 3 and 17
Key Lake, 1998

Species	Site 3		Site 17	
	Unfertilized	Fertilized	Unfertilized	Fertilized
Species	T1 & T2 % Survival	T3 & T4 % Survival	T1 & T2 % Survival	T3 & T4 % Survival
Calamagrostis neglecta	100	96	42	79
Carex foenea	84	92	71	99
Festuca rubra	96	94	81	97
Bromus pumpellianus	72	91	64	94
Mean	88.00	93.25	64.50	92.25

8.1.2 Experimental Plot Jackpine and Deciduous Tree Assessment

In addition to the grasses and sedges, the woody species (willow, birch, balsam poplar, jackpine, pincherry and blueberry planted in the experimental plots at Sites 3, 17 and 21 were also evaluated. The survival of jackpine seedlings is shown below in Table 8.1.5.

Table 8.1.5
Jackpine Survival Rates for the Experimental Plots
Key Lake, 1998

Jackpine Survival Rate (%)				
Treatment	Site 3	Site 17	Site 21	Mean
T1	93.6	99.6	58.5	83.90
T2	87.1	98.9	75.4	87.13
T3	92.1	96.8	81.8	90.23
T4	85.4	100	72.1	85.83
Mean	89.55	98.83	71.95	86.78

8.1.3 Jackpine Seedling Vigor Assessment

Micronutrient Experimental Plots

The four treatment plots and one control plot were compared against each other, and between the 1997 and 1998 sampling years to detect any trends (Table 8.1.6). Jackpine seedlings on micronutrient plots showed increases of 24-89% in mean height, and 33-83% for mean caliper width. At least some of this gain could be attributed to general fertilizing of the entire site that was completed in 1997 and 1998.

Table 8.1.6
Mean Jackpine Seedling Height and Caliper Width for the Different Micronutrient Plots at Site 34

Site 34 Micronutrient							
Plot Designation	Mean Height (cm)			Mean Caliper Width (cm)			Comments
	1997	1998	% Increase	1997	1998	% Increase	
NE	23.2	28.77	24.00	0.75	1.00	33.33	Yellow needles noted.
NW	20.1	33.93	68.81	0.70	1.07	52.86	Yellow needles noted.
SE	18.0	27.94	55.22	0.61	1.05	72.13	Good growth.
SW	17.6	33.25	88.92	0.64	1.17	82.81	Good growth.
Control	18.4	28.61	55.49	0.63	0.94	49.21	Fair growth.

NE: Granular Fertilizer, 40 ml micronutrient in 20 litres of water
NW: 0 Granular Fertilizer, 40 ml micronutrient in 20 litres of water
SE: Granular Fertilizer, 20 ml micronutrient in 20 litres of water
SW: 0 Granular Fertilizer, 20 ml micronutrient in 20 litres of water
Control: 0 Granular Fertilizer; 0 ml micronutrient

Macronutrient Experimental Plots

The macronutrient experiment included manually broadcast fertilizer and containerized macronutrient/slow release fertilizer trials at Site 34. The mean values for caliper diameter and shoot height for the different macronutrient plots are presented, and compared to the 1997 findings, in Table 8.1.7. The percentage increase in shoot height for the jackpine seedlings in the macronutrient trials ranged from 55% to 110%. The trials with the highest increases were the nutricote (110%), Scot high (109%) and Scot low (95%). The control, and two manually fertilized plots, showed increases of 55% and 56% respectively.

Table 8.1.7
Mean Jackpine Seedling Height and Width for the Different Macronutrient/Slow Release Plots at Site 34

Site 34 Macronutrient Trials							
Plot Designation	Mean Height (cm)			Mean Caliper Width (cm)			Comments
	1997	1998	% Increase	1997	1998	% Increase	
Control	18.4	28.61	55.49	0.63	0.94	49.21	Fair growth.
Fertilizer East	20.4	32.15	57.59	0.54	0.91	68.52	Fair growth.
Fertilizer West	20.2	31.55	56.18	0.56	0.97	73.21	Good growth.
Nutricote	19.3	40.68	110.78	0.53	1.23	132.08	Excellent growth.
Scot Low	20.1	39.21	95.07	0.58	1.15	98.28	Good growth.
Scot High	19.5	40.89	109.69	0.58	1.15	98.28	Good growth.

The percentage increases measured for the stem caliper widths showed similar trends with the nutricote trials showing the highest increase (132%), and the control seedlings exhibiting the lowest increase (49%). Again, the containerized fertilizer trials showed higher gains than the control and manually fertilized plots.

8.2 1998 Experiments

8.2.1 Experiment I - Slope Revegetation

A one-in-one-hundred-year storm event occurred at Key Lake in July, shortly after the new test plots were established. As a result, the majority of 1998 slope revegetation plots were severely damaged.

All plots were surveyed in September, 1998. Clay slopes were rated as sustaining more damage than the sand slopes. Water eroded away the clay and formed deep rills in the face of the slope, causing the removal of most of the plants. The sandy slopes also lost some vegetation, however, it appears that the sand was able to dissipate much of the energy from the rain, thereby resulting in less erosion. Plants which remained on the sandy slopes appeared to be healthier than the ones on the clay slopes.

To assess these plots, the number of remaining plants were counted and their vigor noted. Also, the percent cover of planted grass (Hydro plots only) was recorded and the number of stems per square metre counted. This proved difficult for most of the Hydro plots as the water erosion had removed most of the planted seed.

8.2.2 Experiment II

8.2.2.1 Seed Viability/Germination Test

Native Grass Seeds

The germination tests completed under laboratory conditions varied with species and with the growth media used. For example, in clay, germination ranged from a low of 3% for *Calamagrostis inexspansa* to a high of 60% for *C. neglecta*. In sand, germination ranged from 38% for *Bromus pumpellianus* to 69% for *C. inexspansa*. In the petri dish, germination ranged from 14% for C. neglecta to 86% for *Festuca rubra*.

8.3 Visual Assessment of Jackpine Seedling Vigor

Overall, the seedlings planted in the 1993-1995 experimental plots showed little to no decline in survival rates over the past year. The year of planting and the rate change from 1997 to 1998 are as follows: 1993 (decrease from 79.0% to 78.6%); 1994 (no change); 1995 (decrease from 86.6% to 82.7%); and 1996 (Site 34 fertilizer treatment plots decrease from 100% to 98%).

8.4 Seedling Micronutrient Tests

Jackpine seedlings on micronutrient plots showed increases of 24-89% in mean height, and 33-83% for mean caliper width. At least some of this gain could be attributed to general fertilizing of the entire site that was completed in 1997 and 1998.

8.5 Seedling Macronutrient Tests

Macronutrient trials showed increases in mean shoot height per treatment over the past year as being: Nutricote (110%); Scot high (109%); Scot low (95%); manually fertilized (56%); and control (55%). Caliper diameter increases showed the same trends with Nutricote showing the highest increase of 132% and the control seedlings showing the lowest increase of 49%.

8.6 Landscape Assessment of Revegetation Sites

Each of revegetation sites identified in the 5-year management plan was assessed with respect to landscape criteria. The assessment parameters include; Drainage, Erosion, Contour, Stability, Gravel and Rocks, Debris, Vegetation, Bare Areas, Soil and Contamination.

8.7 Permanent Monitoring Plots

The Daubenmire technique (Daubenmire 1959) was used to estimate percentage cover of a permanent monitoring plot. A Daubenmire plot frame (20 cm x 50 cm) was placed in each of the north-west and south-east corners of each of the permanent plots, and the vegetation, detritus and bare ground percentage cover estimated for each of the subsamples. This system utilizes a class system to represent a range of cover by a given species of vegetation or other cover type (*e.g.*, bare ground). The class and percentage cover range are: Class 1 (0-5%); Class 2 (5-25%); Class 3 (25-50%); Class 4 (50-75%); Class 5 (75-95%); and Class 6 (95-100%). The results will be used as a baseline to monitor the health, growth of vegetation and the natural encroachment onto the plots. A detailed presentation of the findings is beyond the scope of this paper.

9.0 Observations/Recommendations

Based on the data presented thus far the following conclusions/observation could be made:

a) Soil stabilization prior to seed germination and or tree planting is a significant factor in establishment of vegetation in any disturbed area.

b) Damages due to wind erosion could severely impede the growth of all species regardless of types. The air borne sand particles are extremely abrasive and sandblast the plants.

c) Due to lack of nutrient in the soil, the plants require nutrient supplements for the first few years before they can become self-sufficient. Th timing and type of the fertilizer are also important factors to be considered.

d) Native species of plants from the Key Lake ecoregion, perform better than standard commercial seed mixtures. The jackpine seedlings, grown from cones collected at the mine site appear to have a better initial vigor than seedlings grown from stock from other ecoregions. The native grass species collected from the Athabasca Sand Dunes, as part of the research component of the project, have performed better than southern grassland/parkland pasture grass mixtures. The native willow, birch and balsam poplar cuttings that were planted are also showing early signs of healthy establishment.

e) Planting jackpine seedlings on bare, exposed sand areas is not practical. Jackpine seedlings appear to need stabilized, semi-sheltered conditions to grow and develop properly. The seedlings are prone to physical damage from blowing sand, and dehydration due to exposure if planted in an unprotected, open area.

f) Although snow fencing is capable of providing good protection for plants during their early establishment phases, it will damage the seedlings and grasses if not maintained.

g) Jackpine seedlings exhibit better growth under conditions where they are protected from being sand blasted.

h) Seed drilling followed by hydromulch application appears to be a good method to achieve the following: accurate seed placement; better seed to soil contact; protection of the seeds; moisture conservation; and erosion control. This would conserve seed and lower input costs. Hydroseeding may cause significant seed mortality and is susceptible to water and wind erosion, particularly if applied sparsely.

i) Mature (>50 years old) stands of jackpine forest in the vicinity of Key Lake have a tree density of 600-1300 trees/ha. And based on the survival rates achieved thus far, it appears a density of approximately 2000 trees/ha is a practical approach.

j) Natural encroachment of native species (*e.g.*, willow, fire weed, blueberry) is occurring to different degrees on all of the sites that have been stabilized. This encroachment is more noticeable on the smaller sites, and around the periphery of the larger sites.

k) Some of the native grass species being experimented with are showing good potential for vegetative expansion (*i.e.*, reproduction through rhizomes) over the growing season. *Calamagrostis neglecta* shows the best expansion potential will be useful for stabilizing steep, sandy slopes. The other grass species exhibit more clumped growth and more seed production.

l) There appears to be several different site conditions within the Key Lake mine site which will require slight adjustments to the revegetation program. Soil textures, slopes, stoniness, aspect, moisture availability and surrounding vegetation are all important factors that contribute to the reclamation protocol required to successfully revegetate the area.

m) To reduce the risk of slope wash out by severe storms, a watershed plan should be developed for waste rock piles and other areas with slopes prior to revegetation.

n) Since different materials behave differently during a severe storm, considerations should also be given to the type of materials (clay vs sand) on slope areas for revegetation.

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